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ABSTRACT

This paper focuses on the notion of human learners as being structure-determined. Alternate views of educational phenomena and educational research of G. Cziko (1989), D. Bohm and F. D. Peat (1987), H. Maturana and F. Varela (1980, 1987), and S. E. Pirie and T. Kieren (1989, 1990) are considered. A mathematical theory of chaos, random behavior/order, and how growth in knowing takes place are discussed. It is proposed that because human behavior is determined at the level of any unity, it is unpredictable. What this unpredictability means for education research is considered. According to structure-determinism, since knowing is recursive and not simply iterative and since the knower is a closed system, a person can know things on many levels and in many ways at once. Thus, a child's behavior (or that of any knower), although determined, is unpredictable both because it is not caused by a stimulus and because the level of response or knowing action cannot be foretold by an observer. It is suggested that education research should shift its focus from viewing educational phenomena as linear successive orders to viewing them as implicate orders. A person's understandings/knowledge can be observed as a recursively numerous set. A theoretical pathway exists whereby an observed understanding can be modeled or placed in a set of understandings. Researchers and teachers should look for patterns over time that might give them a sense of the structures of the children/students with whom they work. Although knowing is unpredictable, the hope and aim of cognitively guided instruction is not a lost cause. Educators cannot seek to cause things by instruction, but to provide experiences (and evaluations), which show their regard for children as individuals, recognize the complexities of their structure, and point them in potentially useful directions. (RLC)

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A Note on Determinism and Predictability in Education Research and Practice*

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"Through habits of thought and language, people have come to take the explicate world of succession as the true ground and the implicate and generative orders as something secondary... It is therefore particularly important that this view be turned around in order to understand reality more deeply."

Bohm and Peat, 1987

Preamble

This essay is called a note for reasons other than its brevity. The discussion below centres around the notion of human learners as structure determined. Structure determinism is a very complex idea which is central to the ontological or cosmological ideas of Maturana and Varela (1980, 1987). It is not an idea which is easily summarized. Something other than a "note" would require a fuller explication. The "structure" in structure determinism refers to the actual processes and relationships between processes that a being can have based on its organization as a member of a biological class, in our case human beings. The arguments raised below are in that sense biological. This essay retains the status of a note because it is beyond its scope (and

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in fact that of its authors) to explicate the biological and neurophysiological organization which undergirds the structure which we observe as the interactions of humans with their environment. Still it is hoped that even this note will point the reader to issues critical in education.

Introduction

Much has been written over the past twenty years on the need to use research methodologies in education which go beyond the gathering and statistical analysis of quantifiable data. Some of the impetus for this comes from those who would see classroom learning as a human phenomenon to be studied using the techniques drawn from anthropology. Others would argue that research should have a pedagogical intent and be for the betterment of the particular learners involved; those learners should not in any way be perceived as generators of data. Still others would say that we need to study the learning person in an environment, rather than study the inter-relationship of abstractions such as SES and achievement.

Cziko in his ER article, among the many things he does, makes a different point. He contends that human behaviour, particularly that in schools is indeterminate and hence unpredictable. In helping make this point he appeals to the modern mathematical theory of chaos and suggests that it might imply that two students who were very close on important measured parameters could end up at the end of a unit or the end of a year with very different measured learnings. He suggests that this

massive difference is a likely product of non-linear iterations on the original "positions" of the learners which typifies human learning behaviour. Such chaotic phenomena are extremely sensitive to small differences in initial conditions. Given this and other examples, Cziko maintains that the nature of the phenomena we are studying implies the need for qualitative methodology with descriptive outcomes rather than quantitative methodologies with predictive outcomes. It could be argued that Cziko, like Bohm and Peat in the quote at the beginning of this note, is asking us to break our habits of form and thought which have found us in educational research focussing on the wrong order of things. Things are indeterminate so they are unpredictable.

The discussion that follows offers an alternative point of view - it is because human behaviour is determined at the level of any unity, that it is unpredictable. Like Cziko, this view asks us to look at the "reality" of the implicate and generative orders. However, it suggests a different basis for that reality and comes to different conclusions about educational research. But before moving to that discussion, let us consider one form of chaotic indeterminate behaviour, random behaviour. Bohm and Peat (1987) suggest that a random order has the following properties. It is of infinite degree. There is no finite description which can predict a particular event. A random order is such that successive events are not significantly correlated. But such an order has a fairly constant average behaviour and tends to vary within limited domains which remain more or less constant or change very slowly. What is interesting for random orders is that while one cannot predict individual events, one can construct a probability distribution which can characterize the phenomenon. (For example the outcome of

flipping a set of a penny, nickel, dime, quarter and dollar cannot be predicted, but the distribution of heads and tails is well known. Thus after repeating 1000 unpredictable events one could give a good estimate of whether the coins were "fair"). Now of course, no one would characterize human behaviour as random although we might at times feel that way about our students and ourselves. The point to be made is that just because events are indeterminate does not mean that quantitative methods cannot be used to help us "predict" the pattern of events.

Structure Determinism

"Everything said is said by an observer. The observer speaks to another observer who could be himself. The observer is a human being, whatever applies to living systems applies to the observer."

H. Maturana in

Maturana and Varela, 1980

The alternative view (to Cziko's) of educational phenomena and educational research is based on key ideas about human beings drawn from the work of systems theorists and ontologists Maturana and Varela (1980, 1987). They maintain that human beings (like other living things) are autopoietic, that is they are self referencing and self maintaining and are in that sense closed systems. They exist in this way in their environment or niche of potential behaviour which can include interactions with themselves and their own mental events. Human beings have language which enables them to observe and to form domains of observation. Human beings accustom themselves to and structurally

couple with elements the environment in which they exist. Events in the environment can act as triggers or perturbations for a person. But the person's response is totally based on the structure(processes and relationships among processes) of that individual allowable by its nervous system and its niche of behavioural possibilities. The actions of the person are not caused by the environment - they are completely determined by her/his structure. This structure allows a person to know things or take effective action in an environment from the point of view of an observer. The previous two points suggest that, from the point of view of the knowers or doers, <u>their actions occur in a perfectly determined way. They act in every instance in accordance with their history and structure. In this biological sense, they are always "right.</u>

Because of the nature of the nervous system, and in particular the use of language, a person's structure and hence a person's knowing is highly plastic. This structure, and the resulting knowing and acting patterns change without destroying the underlying biological organization on which it rests. In particular, humans can observe their own thinking and <u>abstract</u> in the sense that they can distinguish between thoughts which appear to them "caused by the outside world" and those which they see as "their own thoughts"-those which appear internally governed. They can interact with their own mental events and trigger changes within them.

Recursion and its implications

How does growth in knowing take place? Because humans are self referencing, they processes of distinction to change their level of knowing. That is they make distinctions in their action capabilities to coordinate them with the current demands. They can also make distinctions in their distinctions of actions and create mental things for themeselves. Such knowing is seen to occur in interaction with others and growth can occur through many such levels of recursion.

Cziko attempts to make an analogy between a chaotic mathematical process and human learning and knowing. He says such knowing is very sensitive to input variables. Hence, two persons with very slightly different initial measured knowledge, might end up with highly different outcome knowledge after the many iterations which make up knowing. Hence measuring and making predictive models in the standard sense is not fruitful. The phenomenon is indeterminate hand hence unpredictable.

As discussed above, Cziko's view of the phenomenon of study does point us in fruitful directions. It does suggest that learning and hence knowing is a highly complex non-linear phenomenon. But his analogy between mathematical chaos and growth in knowing is faulty on two counts. Mathematical chaos is related to non-linear difference equations, for example

$$(x_{n+1}) = a(x_n)(1 - x_n)$$

where n is the value after n interactions and $0 < x_o < 1$. To make the analogy to learning and knowing Cziko would have to assume that this process is iterative - a process which repeats itself on its outputs on

the same level. Cziko seems to suggest that differences in x_{n+1} are mainly due to differences in initial values of x_o. But in fact, the value of "a" is also critical in determining the nature of the phenomenon. In the example above applied to population proportions, if $a = 2$, the series rather quickly stabilizes at $x_n = 1/2$ regardless of the value of x_o between o and 1. Of course, for values of a between 3 and 4 chaos reigns. Even here some values of "a" lead to non-chaotic results. In fact it is tiny differences in a between 3 and 4 which change the iteration from tending toward chaos to tending toward stability.

Structure determinism addresses both these issues. Knowing is recursive and not simply iterative. The same process of making distinctions creates essentially new levels of phenomena. It is not the same process repeated on essentially the same phenomena, as in the mathematical difference equation. Further, in the mathematical version of chaos, "a" remains constant throughout the iterations. It would seem reasonable that in learning, while one could not change one's initial status, x_o, one could alter the value of "a" in interaction with significant others such as the teacher, fellow students or oneself. Thus it does not appear that the chaos analogy is fruitful in discussing growth in knowing of structure determined human beings.

In trying to look at the complexity of the implicate order of learning and knowing pointed to by Cziko from the point of view of structure determinism, one can consider the constraints on the knowing of an individual. There appear to be two kinds of constraints on the knowing seen by the observer and are suggested by the triadic structure of the evolution theorist Salthe (1985). He sees these as two-fold:

initial conditions and environmental constraints. [It is interesting to note that one can view the environmental constraints in terms of the coefficient "a" in the example above.] In education both of these are of interest to the researcher. In terms of the initiating conditions, one might be interested, for example, in the development of the child as it has impacts on her ability to take particular effective actions. Such research might be exemplified by that of Case and Sandieson (1988) relating instruction to the development of the child. And, of course, regardless of one's philosophical orientation, educational researchers are interested in the effects of environmental constraints on knowing in the classroom. In terms of structure determinism, one would be interested in the types of effective action which were triggered by various aspects of instruction. For example, did a child respond to a particular regime by showing knowledge growth in mathematics or did they simply grow in school survival skills.

In terms of environmental constraints it is useful to remind ourselves of an implication of structure determinism. The child's behaviour is not caused by the environment or the instruction or the teacher. It is not reducible in any predictive way to that instruction (unless that "instruction" is completely suppressive). Because knowing is recursive and because the knower is a closed system, a person can know things on many levels and in many ways at once. Thus, a child's behaviour (or that of any knower), though determined, is unpredictable both because it is not caused by a stimulus and because the level of response or knowing action cannot be foretold by an observer.

To support this let us give a brief example from a recent teaching experiment in which one of us was engaged. Middle school children, aged

12, were receiving their first really formal tutelage on the topic of the arithmetic of fractional numbers. Two children, Jack and Carla were among the 30 students in the class. Both children had histories of lower level achievement in mathematics and both performed at a very low level on the Rational Number Thinking Test (Kieren, 1988) used as a pre-test. Both received instruction in which they worked at reasonably complex dividing up tasks and were asked through instruction to make records of their work using fractional language. Yet their orientation to the tasks and actions were dramatically different. Using the language of Pirie and Kieren, (1989) they made very different distinctions in their activities and had very different images of fractions. Jack was very symbolically oriented and saw fractions as a certain kind of number pair and related fractional notions to numerical patterns. Carla made distinctions in her dividing up behaviour and appeared to have the image that different 'dividings up' or fractions could show the same amount. It is interesting to note that on a paper pencil fraction comprehension post test, Carla did relatively much better on items involving everyday situations or diagrams than she did on symbolically oriented items, while Jack did very well on the symbolic items and poorly on the other items. We would take this to be an illustration of the fact that these two children had different structures and hence responded differently to the same perturbations in the environment, in ways determined by their structures. This not to say that the environment was not important to the observed work of these two students; tracking the patterns of their mathematical understanding over time shows just the opposite. But what we are claiming is that the

performance of the student is not predictably caused by elements in the environment(unless it is a totally suppressive one).

Implications

What does this unpredictability mean for educational research? We think it is useful to remind ourselves, that as researchers we exist in the domain of the observer. This domain is distinct from the domain of the actions we observe. We can try to build models or explanations of educational situations. We simply cannot think that they relate to the knowing as doing from the point of view of that knower.

What kinds of observations can we make? What kinds of theories can we usefully build? Does this view mean that we cannot give teachers any general knowledge of students and their behaviours which might be useful? Must all such information be "local"? With Cziko, the view above suggests that educational research might well shift its focus from viewing educational phenomena as linear successive orders to viewing them as implicate orders. Such orders are non-linear, at least in the sense that they are not well modelled by a single measurement nor even by a set of measurements taken in linear combination (Pirie and Kieren, 1990 AERA paper). We should admit the complexity of what we are facing and relish it. In developing a theory which helps give accounts of the mathematical understandings of the children discussed above, Pirie and Kieren(1990) have attempted to use ideas of recursion to observe these understandings as dynamic wholes. We hypothesize that the understandings of a person can be observed, using the theory, as a recursively

enumerable set. That is, given an observed understanding, there exists a theoretical pathway to model it or place it in the set of understandings. However, this set is not fully recursive. There exist pathways as well as behaviours which are such that we cannot characterise them as understandings or not. Thus this theory is not predictive. Is this a failure in the theory? Perhaps. But it may say something about the phenomenon of mathematical understanding. Penrose(1989) notes that recursive sets have smooth boundaries and that membership in such sets is fully determinable. But recursively enumerable sets have complex and maybe even fractal-like boundaries. Thus it may be that the set of a person's mathematical understandings is simply this complex. If so, we could build linear predictive models of it with smooth boundaries. But in so doing we may be seriously misrepresenting the phenomenon for researchers or for teachers.

Such complexity does not mean we cannot generally model such things as understanding. Nor does it mean that we cannot "measure" them. But it may mean that measurement and analysis need to be done at a different scale and with different theorical bases. As researchers and teachers we can look for patterns over time which might give us a sense of the structures of the children with whom we are working. We can even look for general patterns or theories. Thus, although knowing is unpredictable, the hope and aim of cognitively guided instruction is not a lost cause. We simply have to realize the nature of our models. We cannot seek to cause things by instruction, but to provide experiences (and evaluations) which show our regard for children as individuals, which take cognizance of the complexities of their structures and which point them in potentially useful directions.

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